Comparison of Aircraft Emissions from Los Angeles International Airport to Urban Vehicle Traffic Emissions and its impact on air quality in Los Angeles

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Intoduction

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- Accurate assessment of airport emissions and how they compare to other predominant PM sources, particularly traffic emissions, is essential in understanding the impact of airports on air quality, climate and human health.

- Although efforts have been made to substantially reduce aircraft emissions over the past two decades, these may be offset by growth in the aviation industry and increases in airport traffic (ICAO, 2011).

- The majority of large/international airports are located near heavily populated urban areas, they may have a significant impact on the environment and health of people living in their vicinity.

Objectives

The Los Angeles International Airport (LAX)

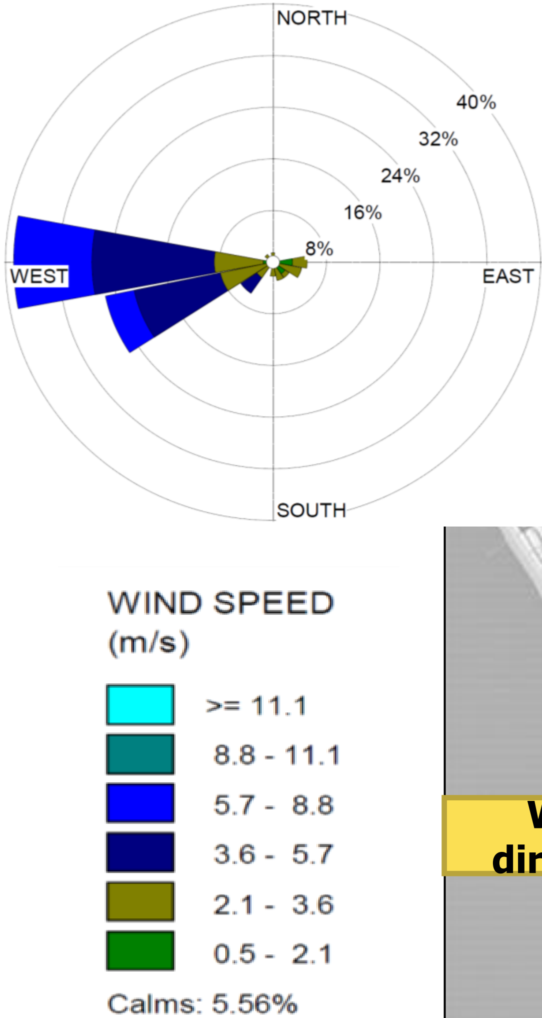
- The Los Angeles International Airport (LAX) is the 5th busiest passenger airport in the world and the 3rd largest in the United States (LAWA, 2014).

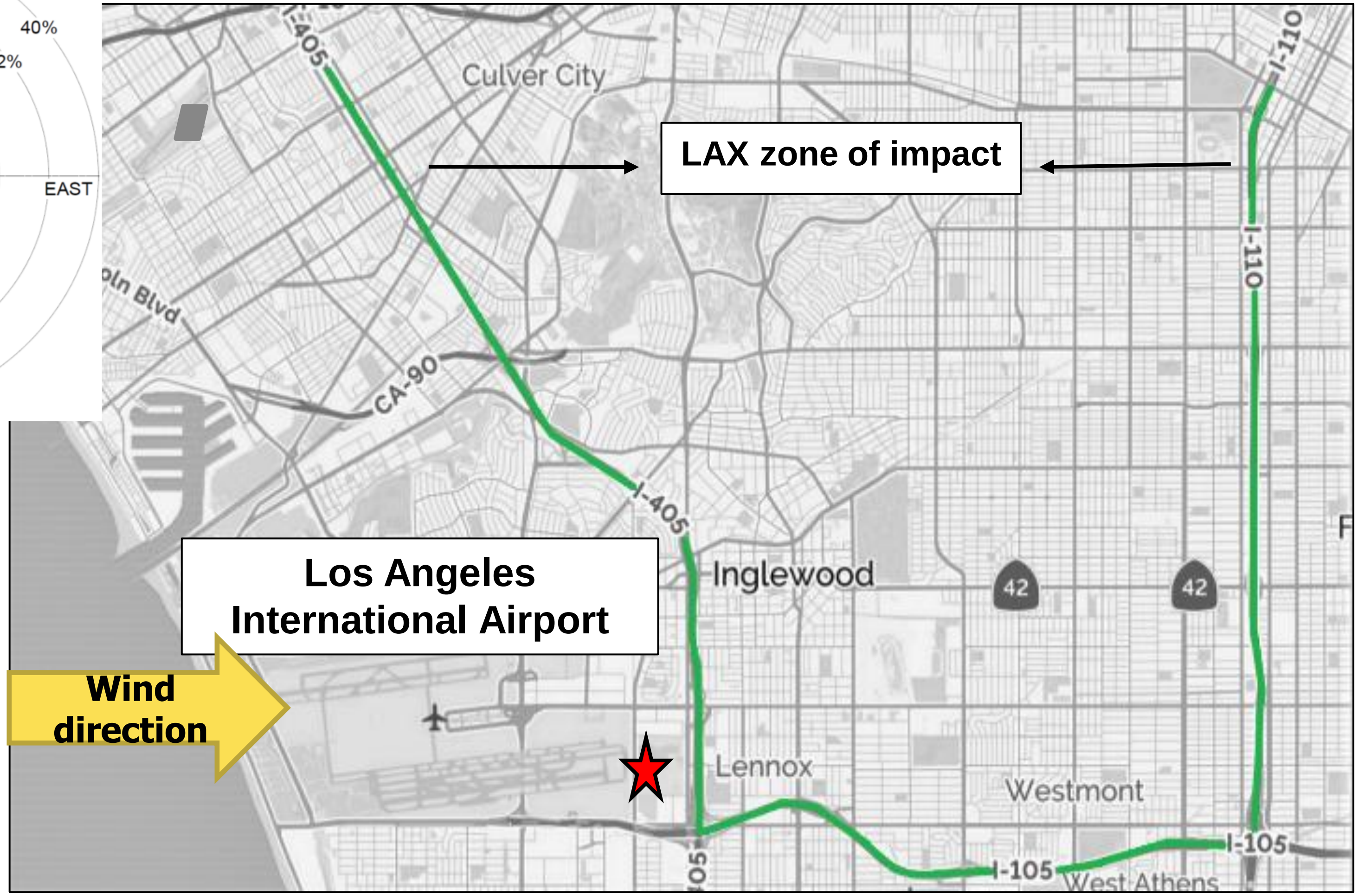
- A recent study, Hudda et al. (2014) measured PN concentrations in the impact zone of the LAX. Results from that study indicated a 5-fold increase in PN concentrations in areas 8-16 km downwind of the airport.

- A large part of the LA population lives in communities immediately downwind of the airport with population density of roughly 14,000 ± 3,500 people per square mile according to U.S. Census 2000 (i.e. roughly 1.5 million people live in the impact zone).

- To the best of our knowledge, no study has so far evaluated systematically the relative impact of aircraft emissions from LAX and their comparison to vehicular emissions from the nearby freeways on the air quality of the area.

Method: LAX Area of Impact





Sampling between May 2016 and July 2016 from 10 a.m. and before 4 p.m. The sampling site, denoted with a star in Fig. 1, was located about 150 m downwind of the south runways.

Methods: Instruments used (analysis run at 1 Hz)

Micro-Aethalometer for black carbon measurements

DustTrak for $PM_{2.5}$ measurements

Garmin GPS

CO_2 monitor

Discmini for number conc measurements

- All of these instruments were operated at a time resolution of 1 s,
- Instrument clock times were synchronized prior to each sampling time to allow for capturing of simultaneous peaks.
- Takeoff and landing times were manually recorded on a log sheet during the sampling period to help later identify plumes attributable to aircrafts.

Methods: Emission factor calculations

Freeway emission factors:

$$\mathrm{EF_p} = \left(\frac{[P]_{fw} - [P]_{bg}}{[CO_2]_{fw} - [CO_2]_{bg}} \right) w_c \times \alpha$$

- P is the concentration of the pollutant;

- [CO2] is the concentration of CO2 (ug of carbon/m^3) measured during the sampling period

$$\mathrm{EF_p} = \left(\frac{[P]_{fw} - [P]_{bg}}{[CO_2]_{fw} - [CO_2]_{bg}} \right) w_c \times \alpha$$

- Wc is the weight fraction of carbon in the relevant fuel, reported as 0.85 for gasoline and 0.87 for diesel (Kirchstetter et al., 1999; Graham et al., 2008).
- "fw" and "bg" denote freeway and background values, respectively.
- Urban background concentrations during each sampling day were estimated as the 5th percentile of the data collected on each freeway
- For BC and PM2.5, [P] has units of ug/m^3 and $\alpha = 10^3$,
- For PN, [P] has unit of particles/ cm^3 and $\alpha = 10^{15}$

Average daily emission rate of pollutant P = EFp *ρ* FC * VMT

- ρ is the fuel density (kg/L); 0.74 kg/L for gasoline and 0.84 kg/L for diesel (Ban-Weiss et al., 2008).

- FC is the average vehicle fuel consumption (L/km); 0.12 L/km and 0.47 L/km for light- duty vehicles (LDVs) and heavy-duty vehicles (HDVs), respectively (Kirchstetter et al., 1999).

- VMT is the vehicle-miles traveled per day. Average traffic count and composition (i.e., the fraction of LDVs and HDVs) and vehicle-miles traveled were obtained from the Performance Measuring System (PeMS) website, operated by the California Department of Transportation

- Freeway-specific values in Equation (2) were obtained by adding the proportional contribution of LDVs (fLDV) and HDVs (fHDV)

- (e.g., $\rho_{-I\ 110}$ = (0.84 kg/L) * (fHDV) * (0.74 kg/L) * (1- fHDV).

Airport Emission Factors

- **Plume identification**

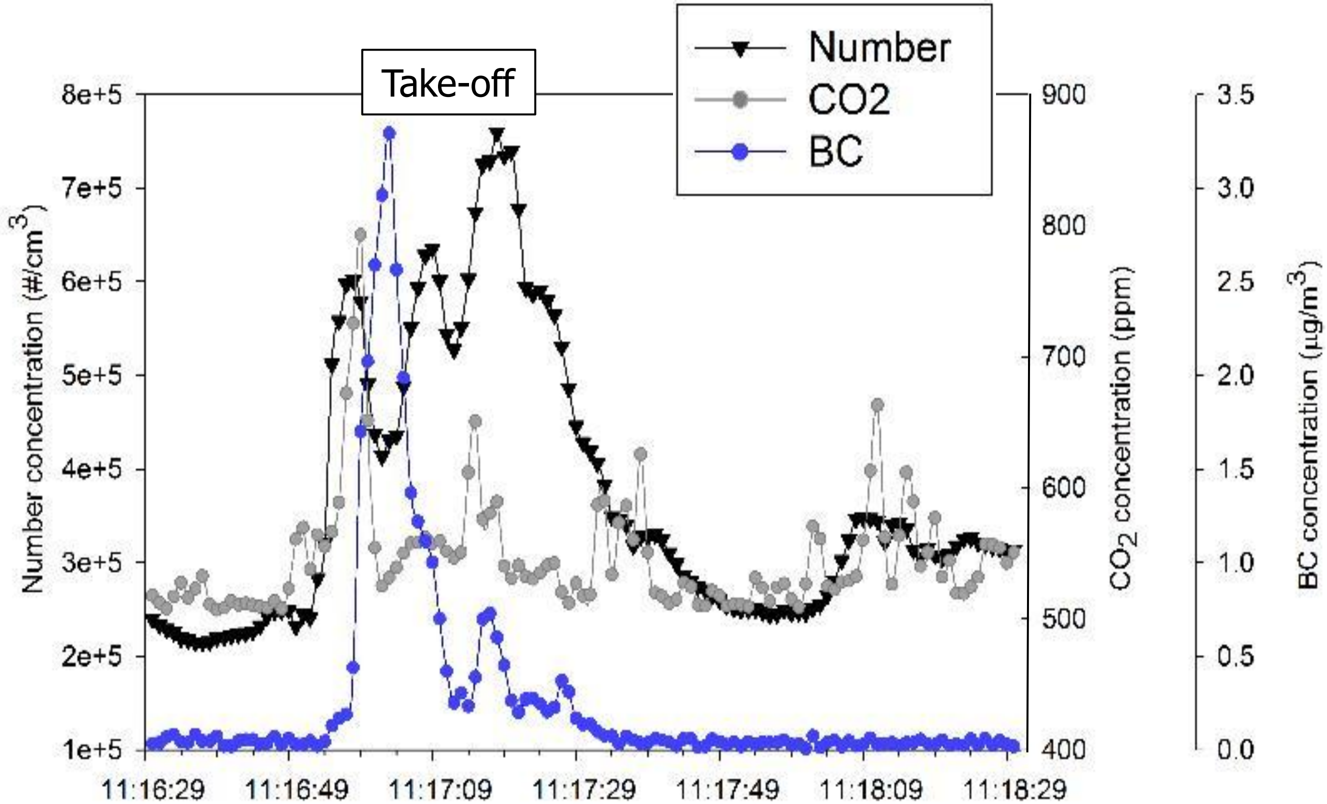
CO2 concentration increases of >25 ppm (Krasowsky et al., 2015) with a concomitant peak in number concentration time series, matched with the exact time of the arrival and departure events from our records by manual inspection.

The emission factor (EF) of pollutant P per unit mass of fuel burned

$$EF_P = (\Delta x/\Delta CO_2)*EI(CO_2)*M_{air}/M_{CO2}*(1/\rho_{air}) \times \alpha$$

Plume analysis

Time series of a portion of the observations at LAX south runway on 06/27/2016 for particle number (particles/cm^3), BC ($\mu g/m^3$) and CO_2 (ppm) concentrations



- A total of 175 plumes were successfully detected (takeoff: 95, Landing 80)

- Aircraft emission analysis was performed on plumes selected based on CO_2 concentration increase of at least 25 ppm (relative to the background levels)

$$EF_p = (\Delta x/\Delta CO_2)*EI(CO_2)*M_{air}/M_{CO2}*(1/\rho_{air}) \times \alpha$$

- Δx is the incremental concentration increase of P compared to the background

- ΔCO2 is the incremental CO2 concentration increase compared to the background (ppm).
- Urban background concentrations were estimated as the 5th percentile of the data collected during each sampling day (Riley et al., 2016).
- EI (CO2) is the emission index of CO2 = 3160 g CO2/kg fuel burned from aircrafts
- Mair and M_{CO2} is the molar mass of air (29 g/mol) and CO2 (44 g/mol),
- ρair is the density of air (1.2 g/L)
- α is a unit conversion factor: For BC and PM2.5, Δx has units of ug/m^3 and $\alpha = 10^{-3}$,
- For PN, Δx has units of particles/cm^3 and $\alpha = 10^9$ (EP_N is expressed in particles/kg fuel burned)

$$EF_p = (\Delta x/\Delta CO_2)*EI(CO_2)*M_{air}/M_{CO2}*(1/\rho_{air}) \times \alpha$$

LAX Average Daily Emission Rate:

$$(\Delta x/\Delta CO_2)*EI(CO_2)*M_{air}/M_{CO2}*(1/\rho_{air})*\alpha*FC*24*3600$$

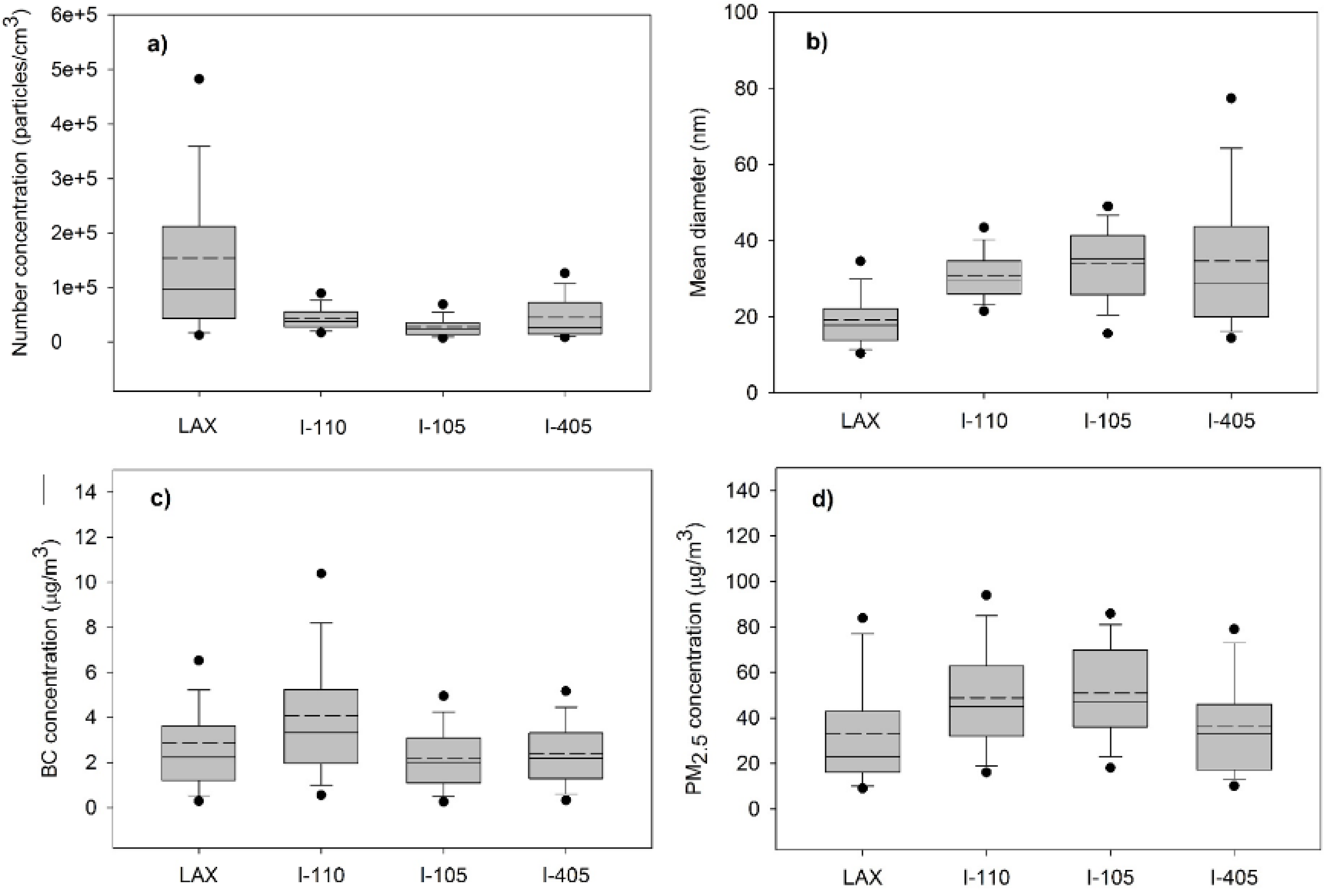
- FC is the aircraft fuel consumption rate (kg/s).

$$(\Delta x/\Delta CO_2)*EI(CO_2)*M_{air}/M_{CO2}*(1/\rho_{air})*\alpha*FC*24*3600$$

- The mean aircraft fuel consumption rates of 1.09 kg/s and 0.31 kg/s during takeoff and landing, were used in our calculations, respectively (EASA, 2010).

- During the sampling period, 51.2 ± 1.7% and 48.8 ± 1.7% of the recorded aircraft activities were attributed to takeoffs and landings, respectively.

Results

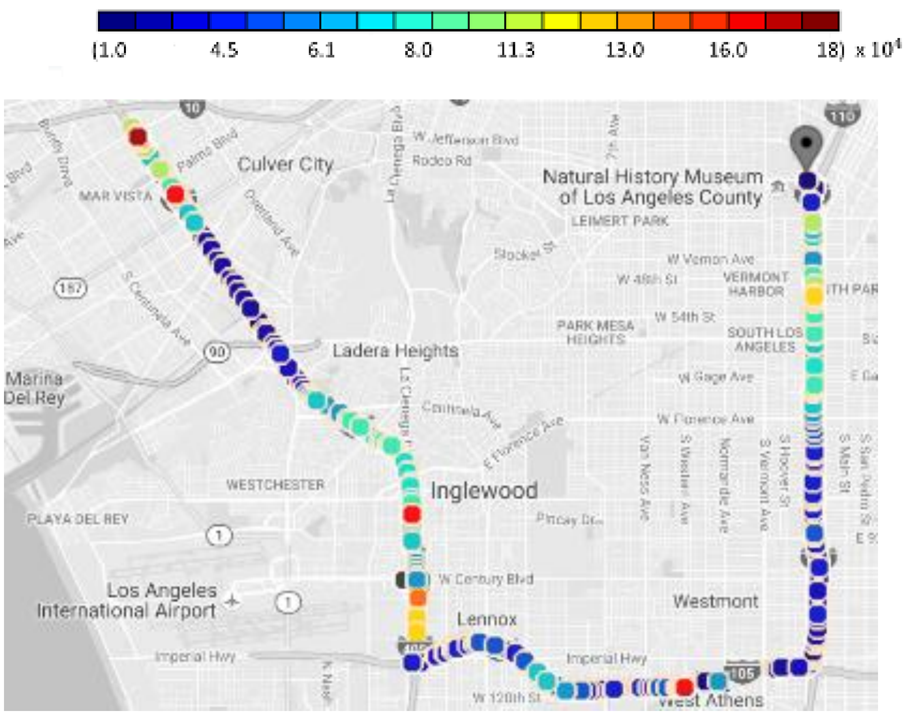


a)
Number concentration (particles/cm^3)
6e+5
5e+5
4e+5
3e+5
2e+5
1e+5
0
LAX
I-110
I-105
I-405
b)
Mean diameter (nm)
100
80
60
40
20
0
LAX
I-110
I-105
I-405
c)
BC concentration (μg/m^3)
14
12
10
8
6
4
2
0
LAX
I-110
I-105
I-405
d)
$PM_{2.5}$ concentration (μg/m^3)
140
120
100
80
60
40
20
0
LAX
I-110
I-105
I-405

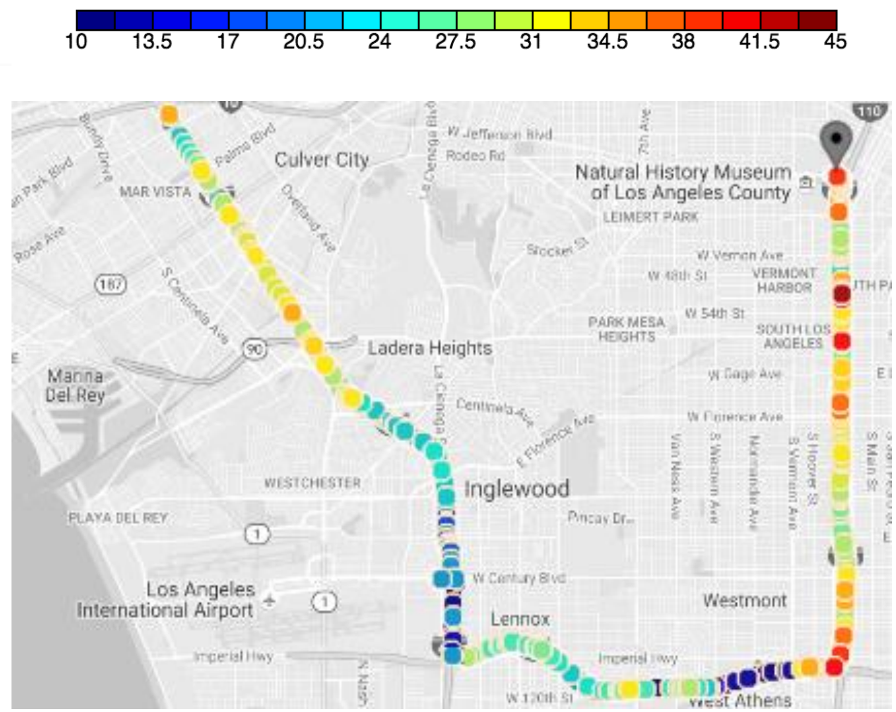
Results

Spatial pattern of particle number concentration (particles/cm^3) and mean particle diameter (nm) measured inside of freeways on June 6, 2016 between 12:00-3:00 PM

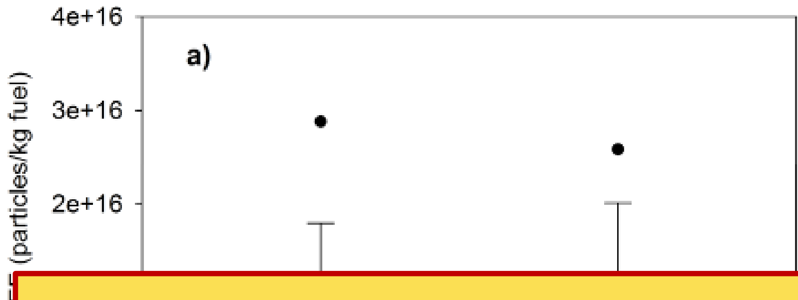
Particle number concentration (Particles/cm^3)

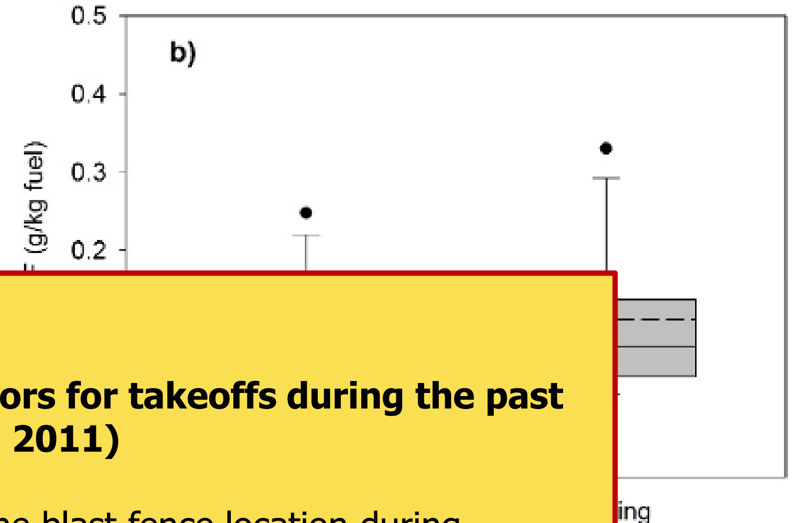


Mean particle diameter (nm)



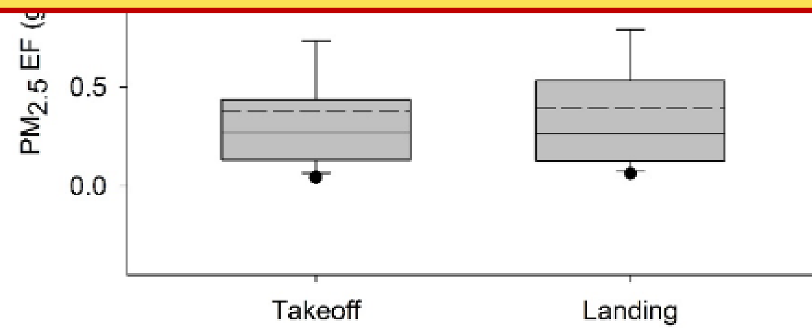
Results: Emission factors



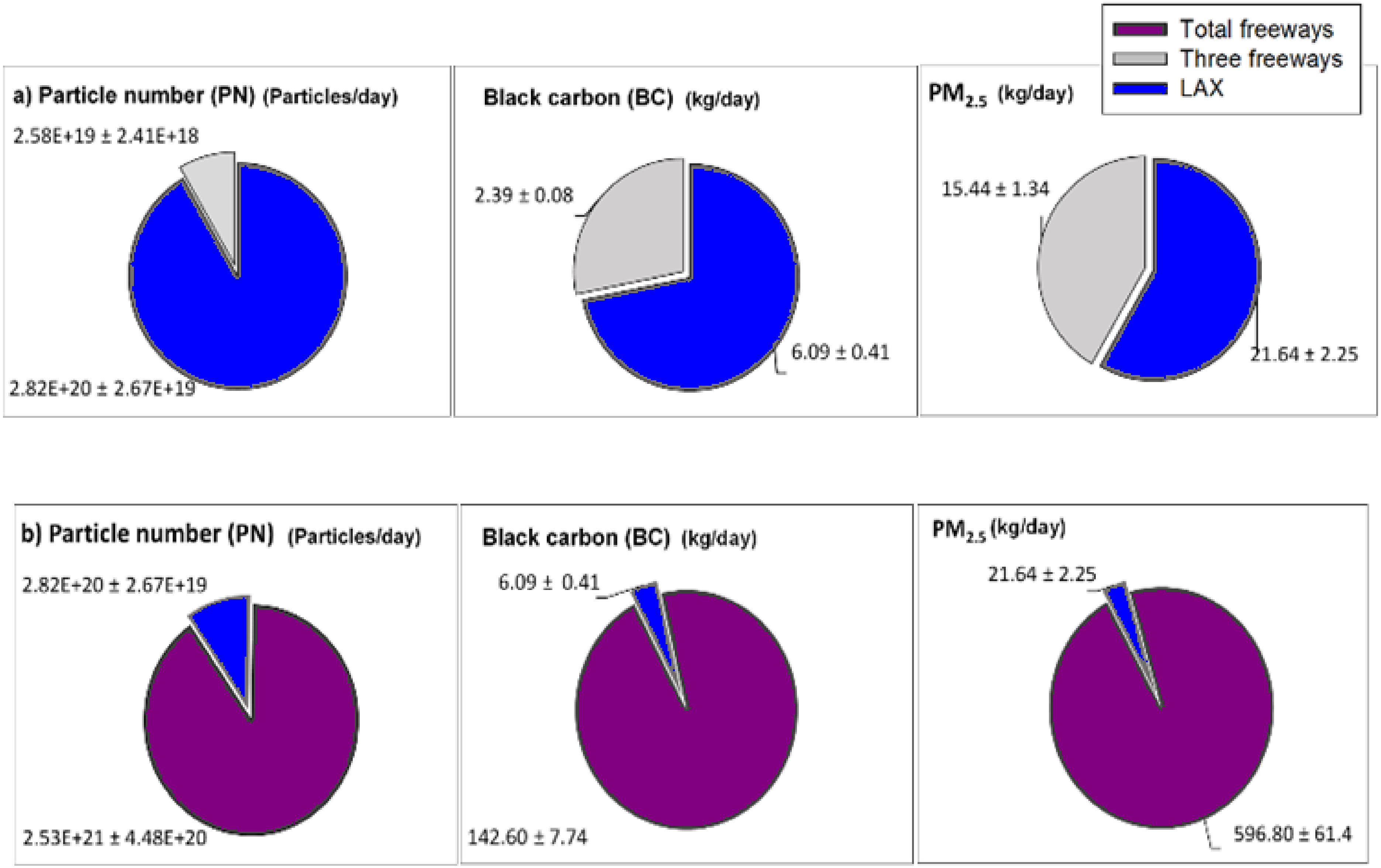


Nearly 4-fold reduction in PN emission factors for takeoffs during the past decade (Zhu et al., 2011)

- Zhu et al. (2011) conducted their sampling at the blast fence location during summer 2005, as well as winter and spring 2006, approximately 140 m away from where aircrafts initiate takeoff on the south runway at LAX airport.
- They reported an average PN emission factor of 3.4 x10^{16} particles/kg fuel during takeoffs for the size range of 7-320 nm



Results: LAX Emission rates vs freeways



Conclusions

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- We demonstrated that the LAX airport has a significantly higher impact on air quality degradation within the neighborhoods in its vicinity compared to the three major freeways (i.e. I-110, I-105, and I-405) traversing the area.

- Daily emission rates of PN, BC, and PM2.5 mass from the LAX airport were 11, 2.5, and 1.4 times greater than the sum of the three freeways.

- Particle number emission factors for takeoffs and landings were comparable, with average values of $8.7*10^{15}$ particles/kg fuel and $8.1*10^{15}$ particles/kg fuel, respectively, and indicated a nearly 4-fold statistically significant reduction in PN emission factors for takeoffs during the past decade.

- Results from this study provide significant insight on the extent of the contribution of the LAX airport versus local freeways to ambient UFP and BC concentrations, and will be helpful in future epidemiological studies evaluating the health impacts associated with proximity to this major source of air pollution.

Acknowledgements

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Thank you!